Laboratory of ELECTROMAGNETIC THEORY

Experimental investigation of a linear Van Atta reflector

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Scientific Report No. 3 S 127 R 46
Contract No.AF61(052)-794 May 1965

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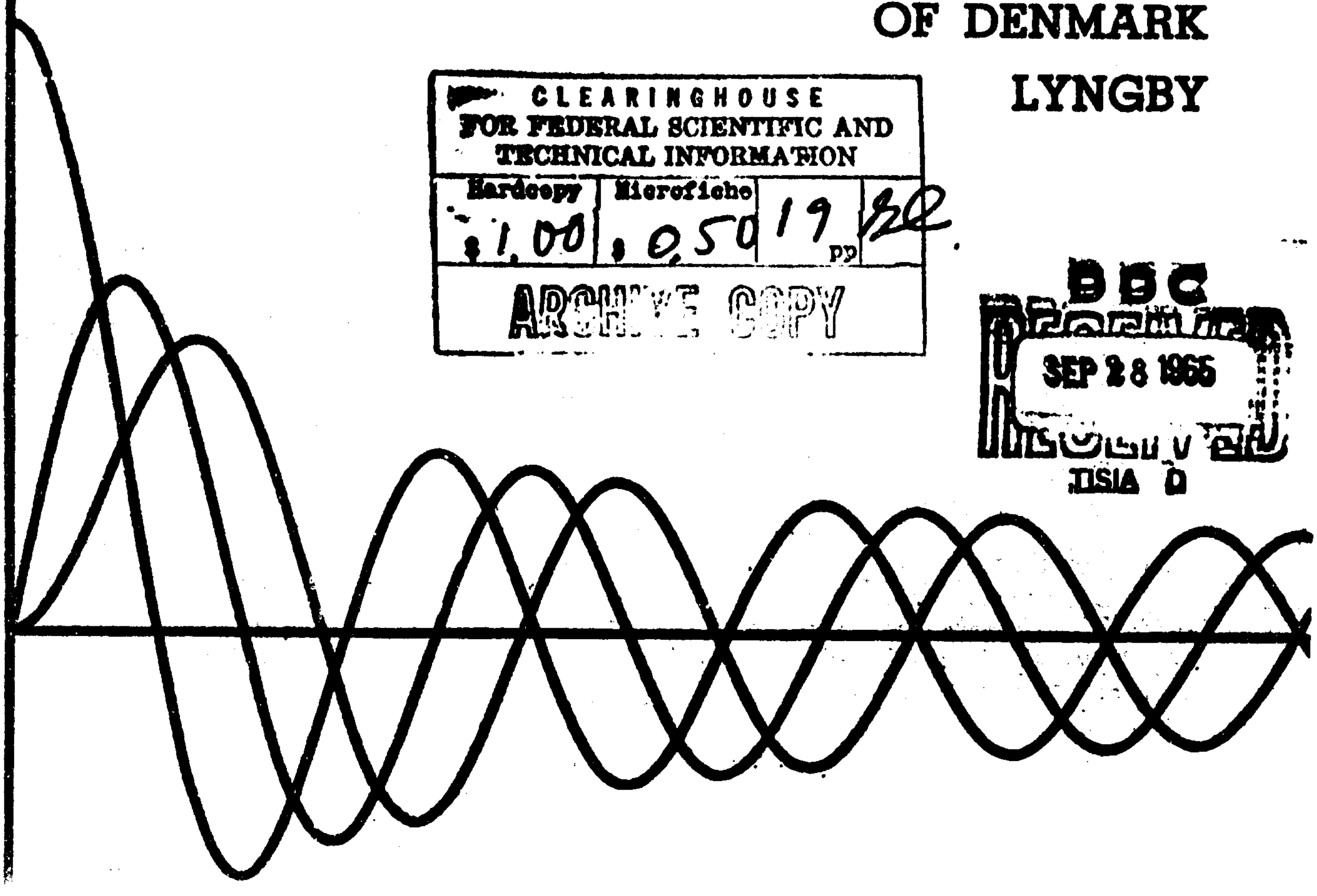

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The research reported in this document has been sponsored in part by the AIR FORCE CAMBRIDGE RESEARCH LABORATORIES, OAR under Contract AF 61(052)-794 through the European Office of Aerospace Research, (OAR), United States Air Force.

ABSTRACT

An experimental investigation of a linear Van Atta reflector consisting of four half-wave dipoles has been made in a radio-anechoic box.

In agreement with a theoretical and numerical investigation, the experiments show that the reflector has the effect stated in Van Atta's patent description only to a limited extent. It has been confirmed that maximum reflection in many cases is not back in the direction of incidence and that the reflector has a mirror effect to tl same extent as it has the Van Atta effect.

Furthermore it has been verified that for certain lengths of transmissionlines and angles of incidence there is no reflected field. Asymmetries in the reradiation patterns have been observed which, according to theory, are due to mutual coupling between the dipoles.

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1. INTRODUCTION

Since Van Atta (1) first proposed his reflector in 1956 several papers have been written on reflectors based on the Van Atta principle. Apart from Van Atta's patent description (1) the simple reflector is dealt with only in some experimental investigations made by Sharp, Fusca and Diab (2, 3, 4). They have measured the back-scattering cross section but not examined the reradiation patterns and the influence of the length of the transmission lines connecting each pair of antennas.

In scientific report no. 1 and 2 (5, 6) theoretical investigations of the reradiation patterns and the influence of the length of the transmission lines have been made. Some results have been obtained which disagree with the idea of the patent. The main results are:

1. The maximum reradiation is not always back in the direction of arrival of an incident wave.
2. The reflector has a mirror effect to the same degree as it has a Van Atta effect.
3. The reradiation depends on the length of the transmission lines.
4. There are assymmetries in the reradiation patterns.

It is the purpose of this report to show the agreement between the four conclusions mentioned above and some experiments made in a radio-anechoic box.

2. EXPERIMENTAL ARRANGEMENT

The Van Atta reflector investigated experimentally is shown in fig. 1. The four half-wave dipoles are slot fed dipoles with open-ended terminations. Line-stretchers are inserted in the transmission lines connecting the dipoles. This is done in order to investigate the influence of the length of the lines on the reflecting properties of the dipoles. The measurements are performed at 3.21 GHz, where the best matching between each dipole and its transmission line is obtained. The distance between the dipoles is o.54 λ.

The reflector is placed on a movable pedestal in the middle of the anechoic box (fig. 2). The experimental arrangement is shown in fig. 3. The measurements are based on the principle of interference between two signals. When the pedestal is moved, the phase of the signal reflected by the dipoles will vary. This signal, which is the one we want to measure, interferes with a reference signal composed of reflections by the walls of the anechoic box and a signal introduced into the receiving system by the connection between the transmitting and the receiving system. By varying the amplitude and phase of the latter signal, it is possible to produce a reference signal of the same order of magnitude as the measured signal. This is done in order to have a measurable interference. In fig. 4 is shown, as an example, a photograph of a series of interference pictures.

In a single series of measurements of reradiation pattern the maximum angle over which measurements can be made is 70° (see fig. 5) because of the small size of the anechoic box. However, it is possible to combine two series of measurements so that the radiation pattern for a fixed angle of incidence is measured in an interval of 140°. Radiation patterns have been measured in the plane normal to the axes of the dipoles. The incident wave was polarized parallel to the dipole-axes.

3. COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL RESULTS

3.1 Measurements performed.

Radiation patterns have been measured when the direction of incidence is 30°, 60°, 70° and 90° with respect to the plane of the reflector. For each angle of incidence the length of the line-stretchers has been varied in steps of 1 cm (= 0.11 λ) over a wavelength. All reradiation patterns have been measured at intervals of 5°.

In order to compare the experimental and the theoretical results a normalization was chosen such that there is agreement between the level of the experimental and theoretical maxima of back-scattered energy for normal incidence. The theoretical and normalized experimental results are shown in fig. 6. The inherent bistatic angle between the receiving and the transmitting horns is taken into account by using the theoretical value for the reflected energy at an angle of 5° with respect to the normal to the plane of the reflector.

The experimental reradiation patterns are shown in figs. 7 to 10 together with the theoretical reradiation patterns obtained by means of the computer program used in Scientific Report No 2.

3.2 Discussion of results.

In the following analysis, the four results mentioned in the introduction will be deduced from the measurements when the angle of incidence is 60°, 70° and 90°. The measurements at 30° will be discussed separately.

From figs. 8 and 9, where the angles of incidence are 70° and 60° respectively, it appears that there is not always a maximum of reflection back in the direction of incidence. The deviation is, except for a few cases, not more than 5°.

Figs. 8 and 9 indicate that the reflector has a mirror effect to the same degree as it has a Van Atta effect i.e. when the angle of incidence is ϕ_i the reflector has a maximum of reradiation which does not deviate from the direction $\pi-\phi_i$ more than the maximum which corresponds to the Van Atta effect deviates from the direction ϕ_i and one maximum is not more pronounced than the other.

All the radiation patterns illustrate that the reradiating properties of the reflector depend on the length of the transmission lines. At normal incidence (see fig. 7) it appears that the magnitude of the reflected energy is very dependent on the length. When the length is about one wavelength the reflection

is negligible. At oblique incidence the dependence is not as large as at normal incidence. In fact, when the angle of incidence is 60°, the dependence is small.

The asymmetries in the radiation patterns, which are due to the mutual coupling between the dipoles, are evident by the radiation patterns in figs. 8 and 9. At 70°, the mirror effect is in many cases more pronounced than the Van Atta effect.

The radiation patterns at 30° in fig. 10 require a detailed discussion. A single symmetrical loop in the direction $\phi = 0$ is to be expected from the theoretical results. However, there is neither a single loop nor symmetry. As in the patterns at 70° and 60°, there is a loop near the direction of incidence ($\phi = 30^{\circ}$), except in two cases where the maximum is small and the direction of maximum reradiation deviates considerably from the direction of incidence. When these exceptions are not taken into account the measurements may indicate that at small angles of incidence the reflector behaves more in accordance with the patent description than could be expected from the theoretical results. However, it is not so that the disagreement between the theoretical and the experimental results gives the above statement. This is because of (a) the large asymmetry about the direction $\phi = 0^{\circ}$, (b) the loop near the direction $\phi = 30^{\circ}$ usually is not very pronounced, and (c) the reradiation in the directions $\phi = 0^{\circ}$ is larger than the maximum of the loop.

It is seen that the measurements to a considerable extent confirm the four theoretical results stated in the introduction.

3.3 Sources of error.

Some sources of error which may cause deviations between the experimental and theoretical results are the following:

1. Reflections from the line stretchers, the transmission lines and the mounts for the dipole wings and connectors placed behind the dipoles influence the results.

2. In the theoretical investigation, approximations are made which may cause discrepancies between the numerical and the experimental results. One of these is that the theoretical values used for the mutual impedances are calculated for two half-wave dipoles in free space. The fact, that the mutual impedance of any two dipoles depends on the presence of the remaining two is neglected. Furthermore, the dipoles are not exactly one half-wavelength long at the experimental frequency. This is because the experimental frequency is chosen such that the best possible matching between each dipole and its transmission line is obtained (SWR = 1.25).

3. A mismatch in the transmission lines is introduced by the linestretchers.

4. The component of the reference signal in the experimental set up which is due to the reflections from the room is changed when the pedestal is moved.

5. The movement of the pedestal changes the angle of incidence.

6. Reflections from the pedestal itself can not be separated from the reflections from the reflector.

The first of the above mentioned sources of error may explain why the loop in the mirror-direction has a tendency to split up into two loops when the directions of incidence are 60° and 70° (see figs. 8 and 9). This is caused mainly by the linestretchers which are placed parallel to the plane of the reflector and therefore will give a greater disturbance in the mirror direction than in the Van Atta direction. Likewise the splitting up, at an angle of incidence of 30°, into two loops may be due to reflections from the mounts for the dipoles and the connectors.

4. CONCLUSION

An experimental investigation of a linear Van Atta reflector consisting of four half-wave dipoles has been performed in order to confirm the following theoretical results:

1. Maximum reradiation is not always back in the direction of arrival of an incident wave.
2. The reflector has a mirror effect to the same degree as it has a Van Atta effect.
3. The reradiation depends on the length of the transmission lines.
4. There are asymmetries in the radiation patterns.

There is considerable agreement between the experimental and theoretical results. The discrepancies between the theory and the experiments is explained by the sources of error. The most serious of these is the reflection from the linestretchers, the transmission lines, the mounts for the dipole wings, and connectors placed behind the dipoles.

5. LITTERATURE

(1) L.C. Van Atta, "Electromagnetic reflector". U.S. Patent no. 2908002, serial no. 514040, (Oct. 6, 1959).

(2) E.D. Sharp, "Properties of the Van Atta reflector array". Rome Air Dev. Center technical report 58-53, AD 148684, (April 1958).

(3) J.A. Fusca, "Compactreflector has e.c.m. potential". Aviation Week, p. 66-69, (January 5, 1959).

(4) E.A. Sharp and M.A. Diab, "Van Atta reflector array". IRE Trans. PGAP, Vol. AP-8, p. 436-438, (1960).

(5) Tove Larsen, "A theoretical investigation of Van Atta arrays". Scientific Report No. 1, Contract No. AF 61(052)-794, Laboratory of Electromagnetic Theory, Technical University of Denmark, (Nov. 1964).

(6) J. Appel-Hansen, "Linear Van Atta reflector consisting of four half-wave dipoles". Scientific Report No. 2, Contract No. AF 61(052)-794, Laboratory of Electromagnetic Theory, Technical University of Denmark, (Nov. 1964).

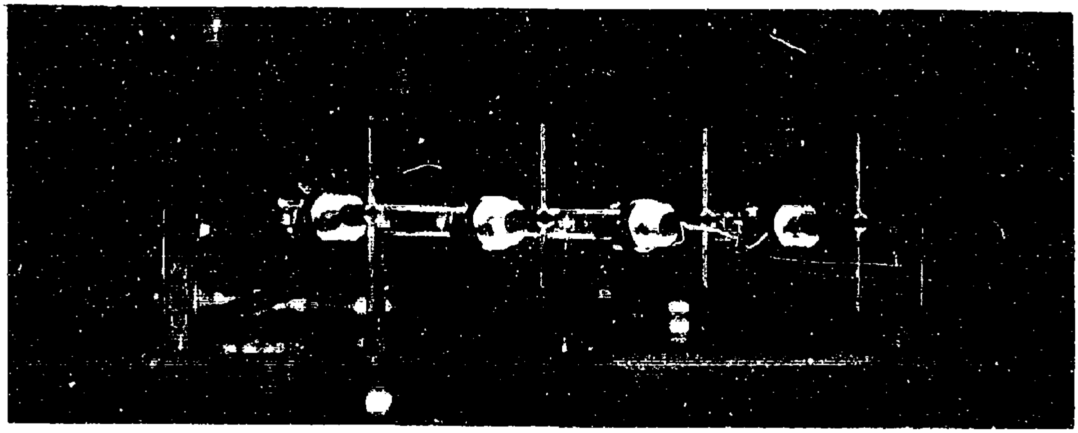

Fig. 1. Four element Van Atta reflector

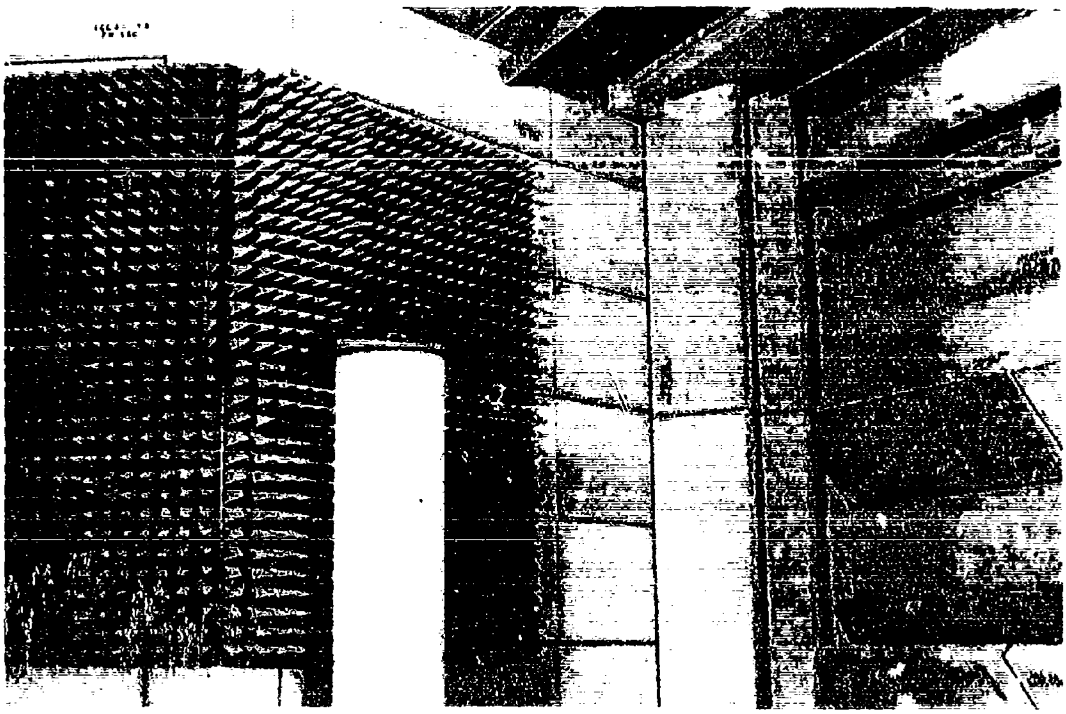

Fig. 2. Van Atta reflector placed on pedestal in radioanechoic box

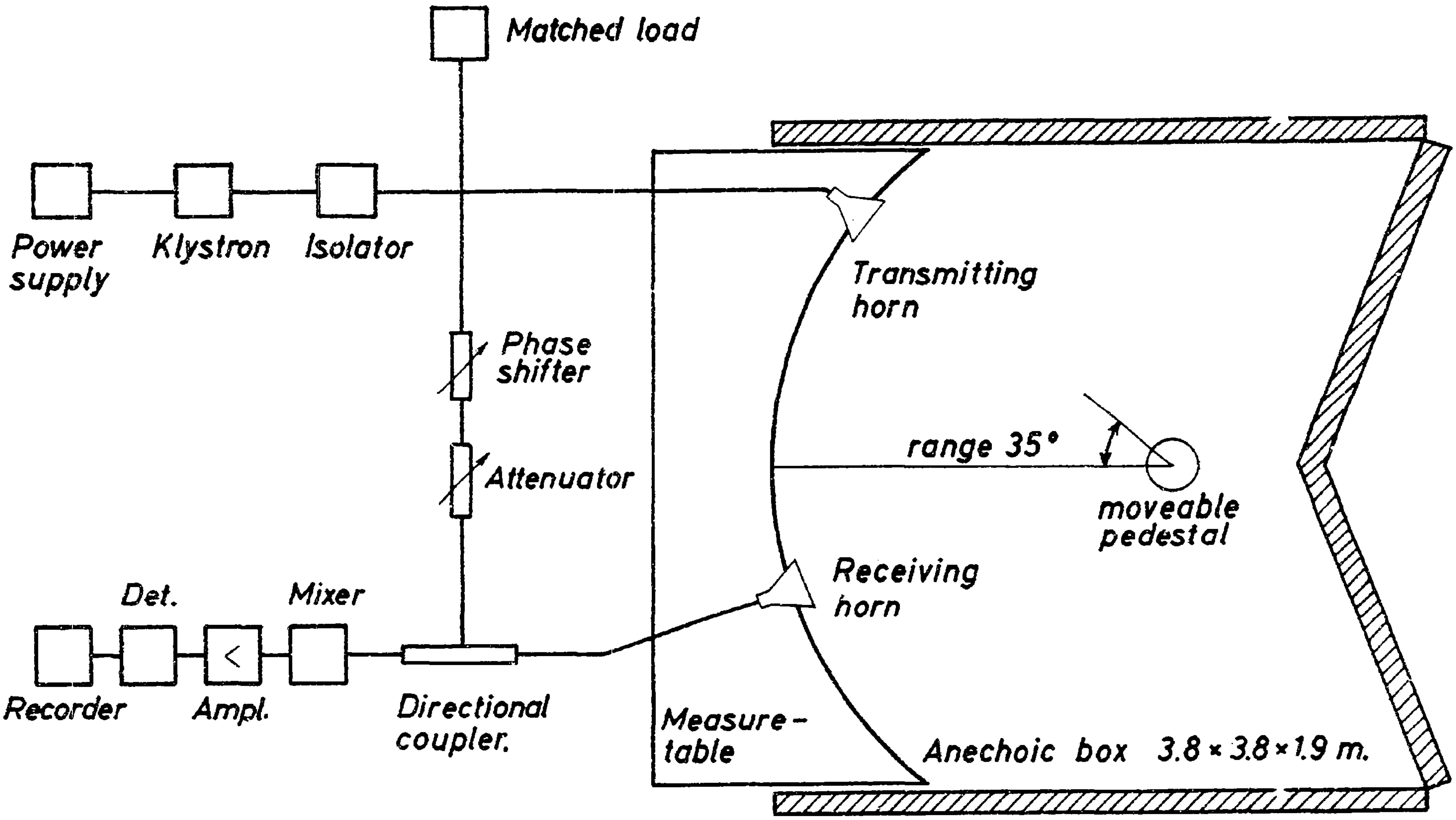

Fig. 3 Experimental arrangement

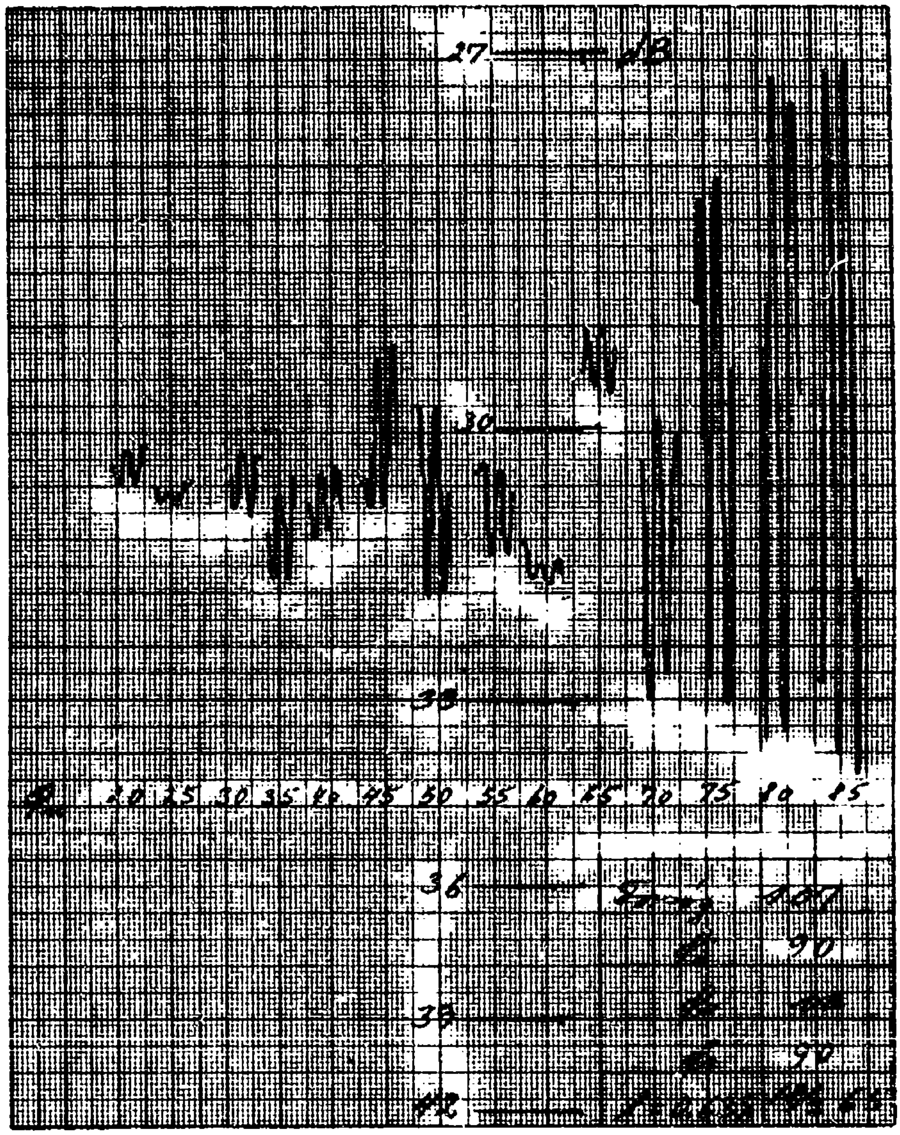

Fig. 4 A series of measurements for normal incidence. Compare with fig. 7, $l = 0{,}63\lambda + p\lambda$.

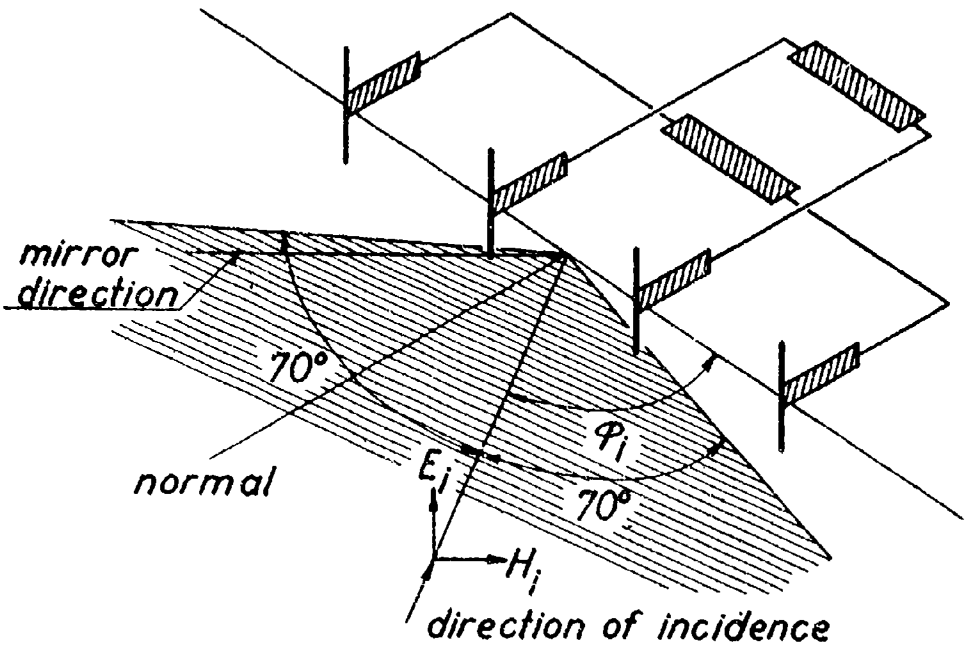

Fig. 5   Geometrical configuration.

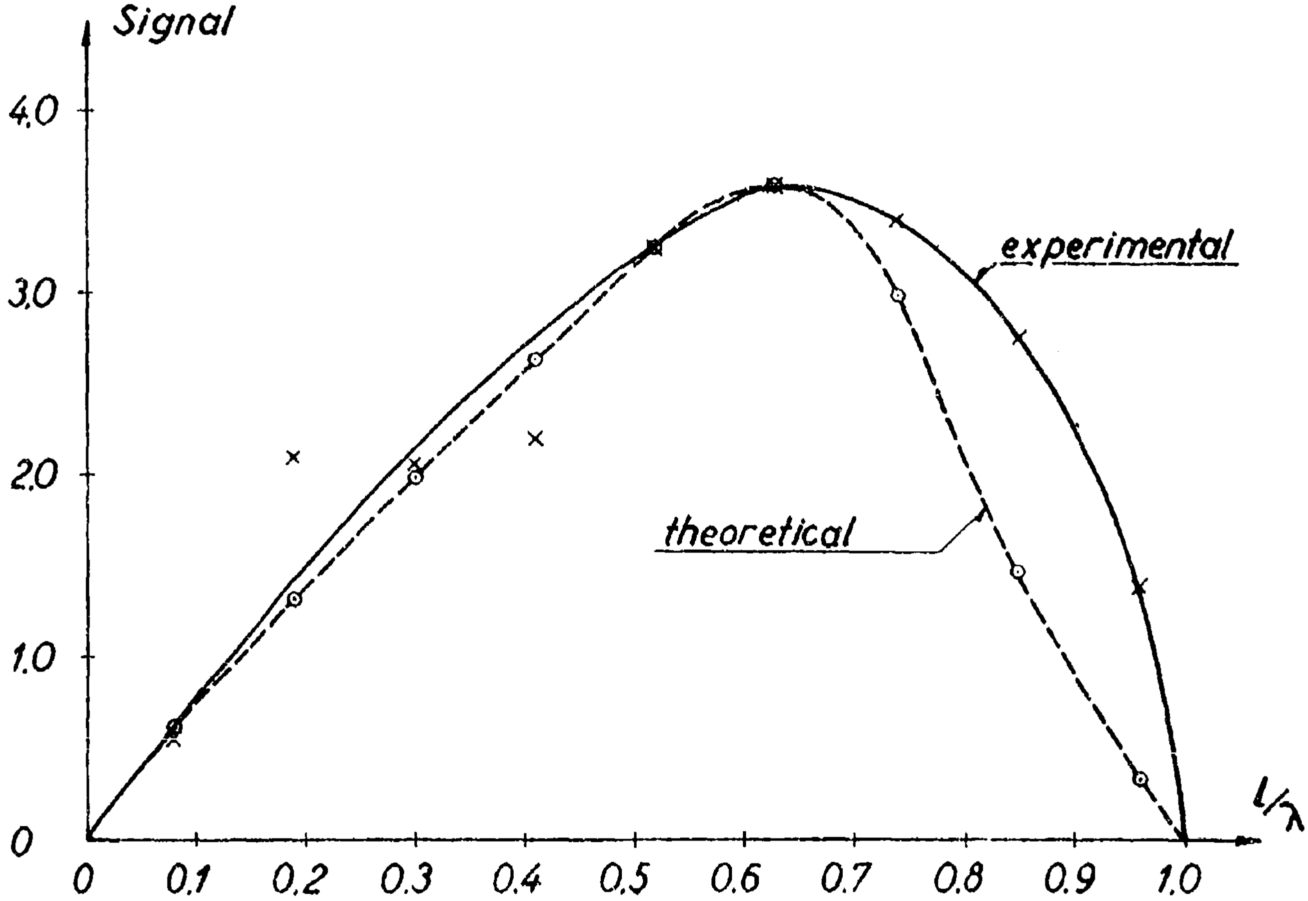

Fig. 6 Back scattered energy for normal incidence as a function of the length of the transmission lines

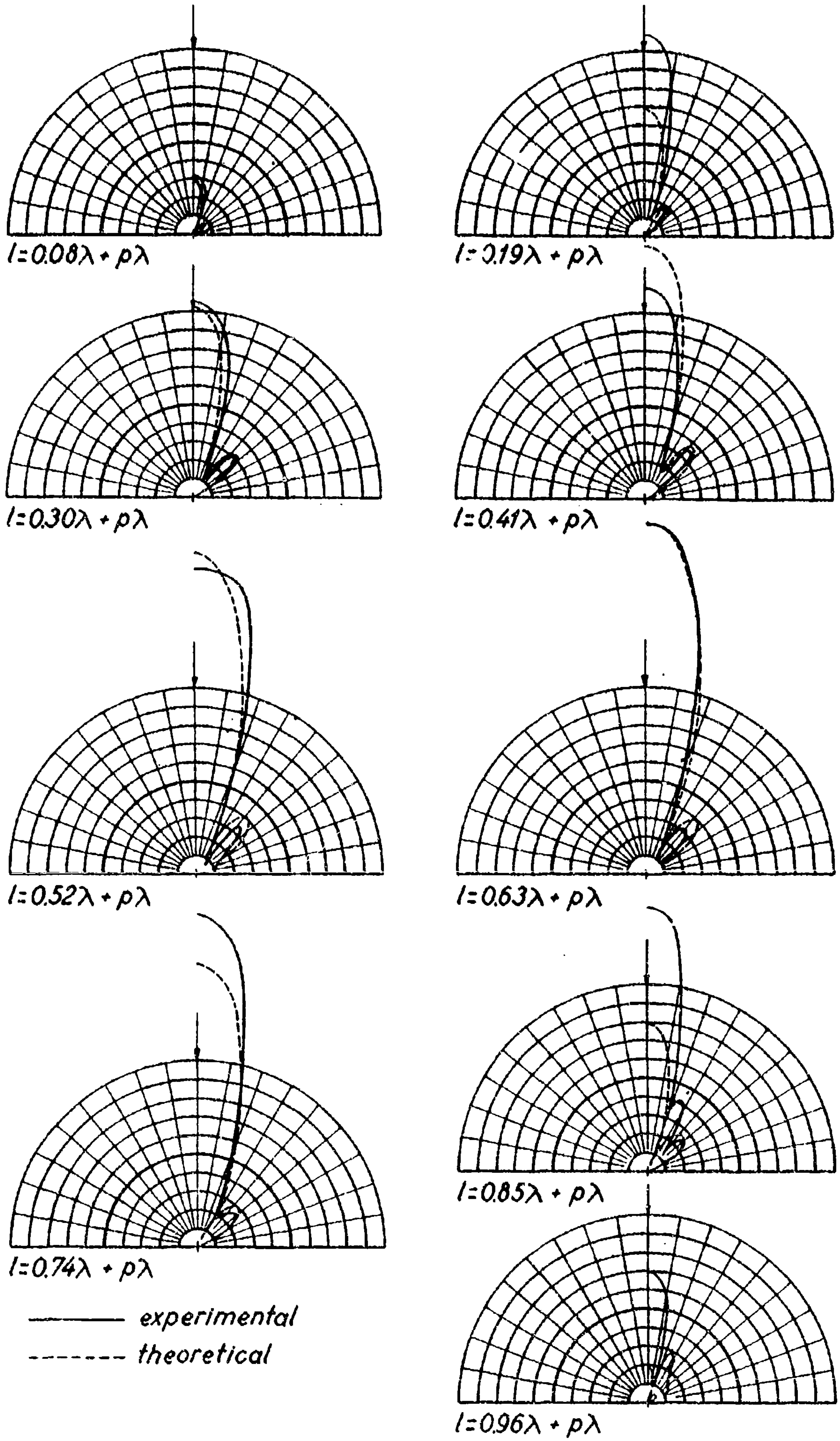

Fig. 7. Radiation pattern as a function of the length of the

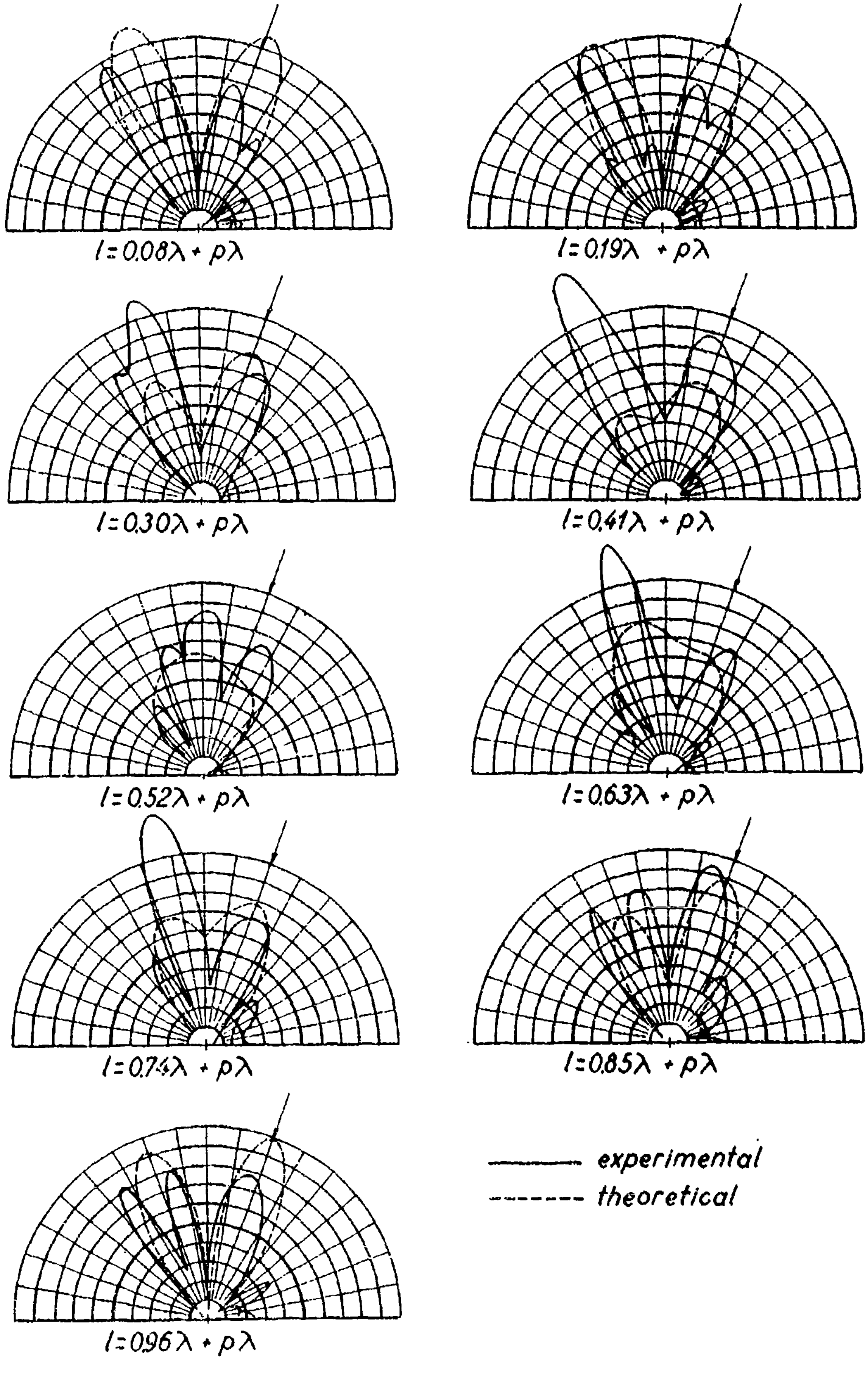

Fig. 8 Reradiation pattern as a function of the length of the transmission lines, $\varphi_i = 70°$

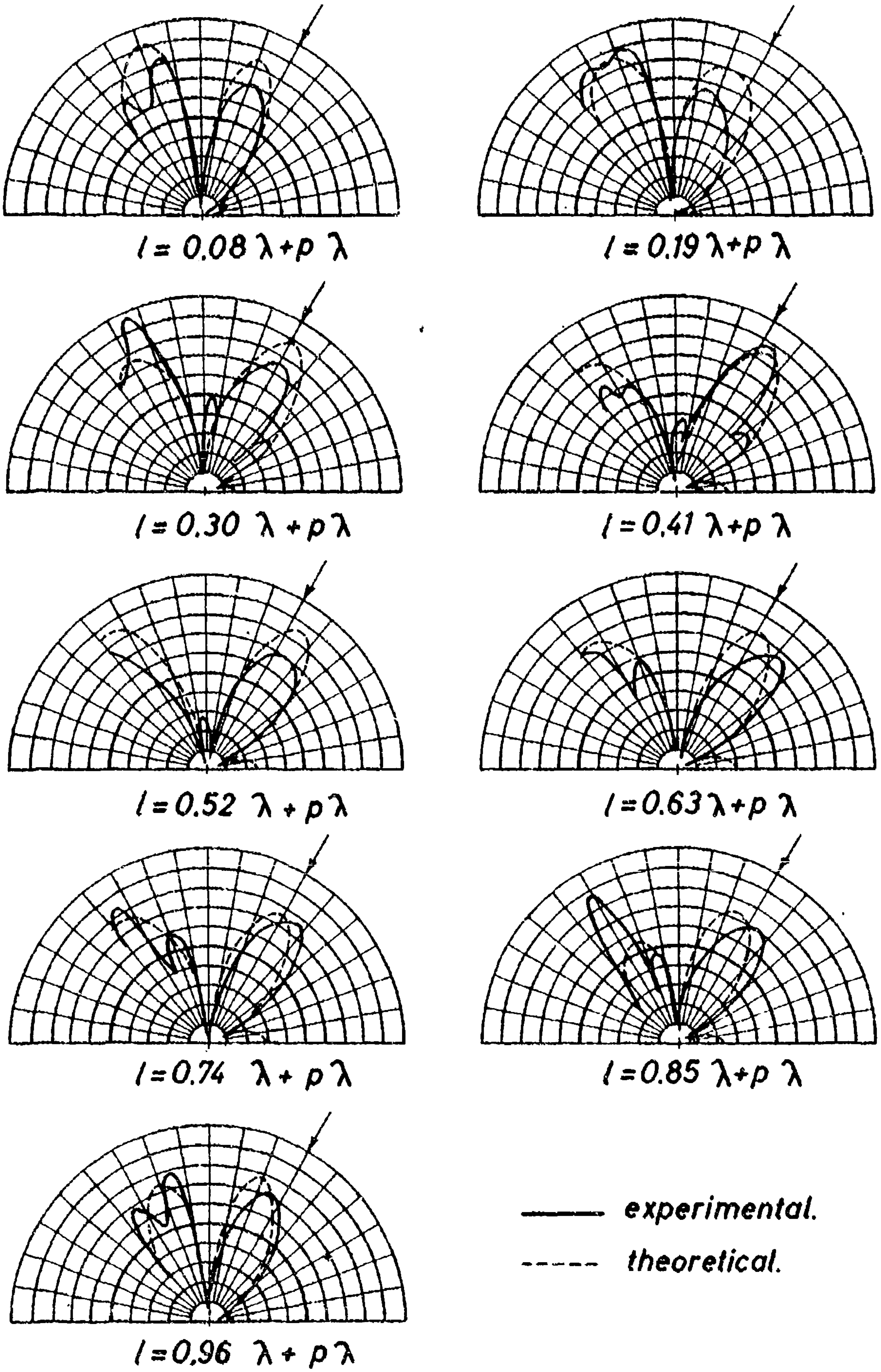

Fig. 9 Reradiation pattern as a function of the length of the transmission lines $\varphi = 60°$

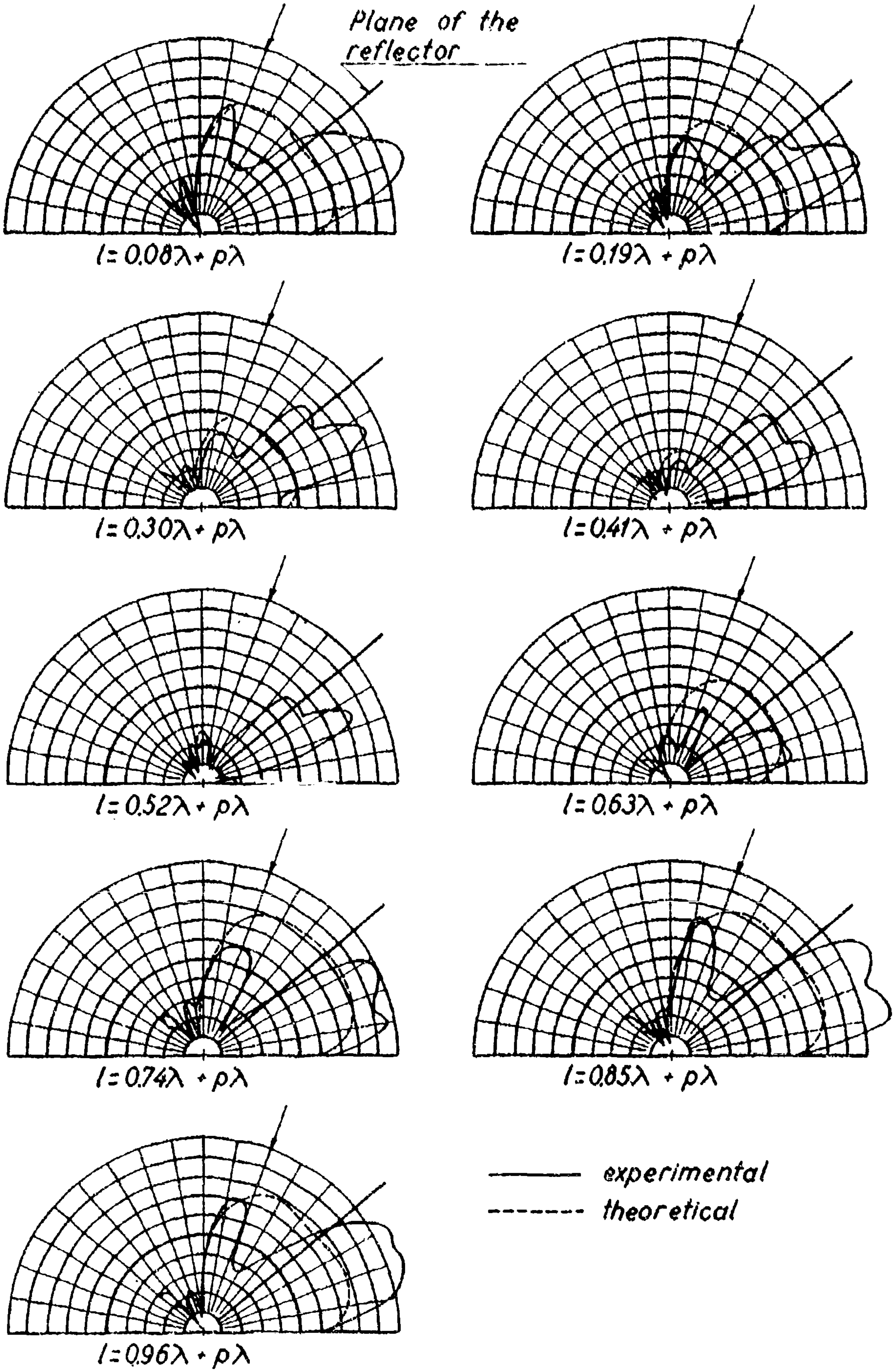

Fig. 10 Reradiation pattern as a function of the length of the transmission lines. $\varphi_i = 30°$